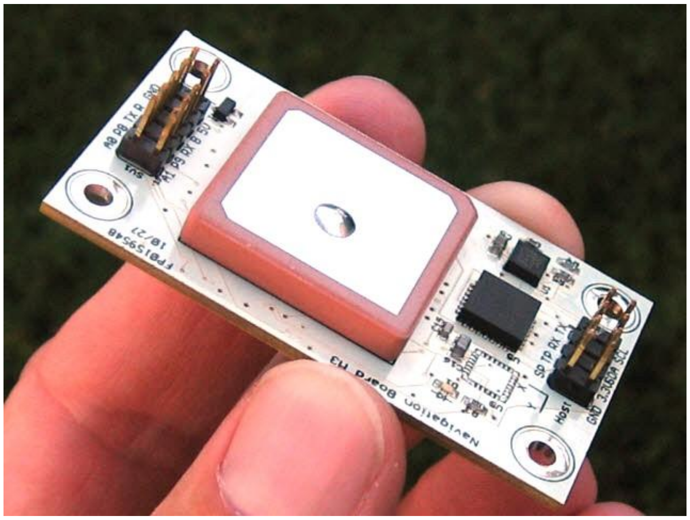
Navigation Board M3
User Manual



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Subtitle	NavBoard M3 User Manual		
Type	Manual		
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Initial Release	9/2010	MR	Initial release
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B	8/2011	MR	Test software output example

IMPORTANT DISCLAIMERS

1. Introduction

The Navigation Board M3, or NavBoard M3, is a miniature GPS and inertial measurement unit (IMU) package designed for either stand alone operation with on board processing or simply as a sensor package for integration into existing systems.

The NavBoard has an excellent GPS module on board (U-Blox series) with both on board and off board antenna capability. The off board antenna capability is important if the unit is used in conditions where the on board antenna will be blocked by enclosures or other jamming.

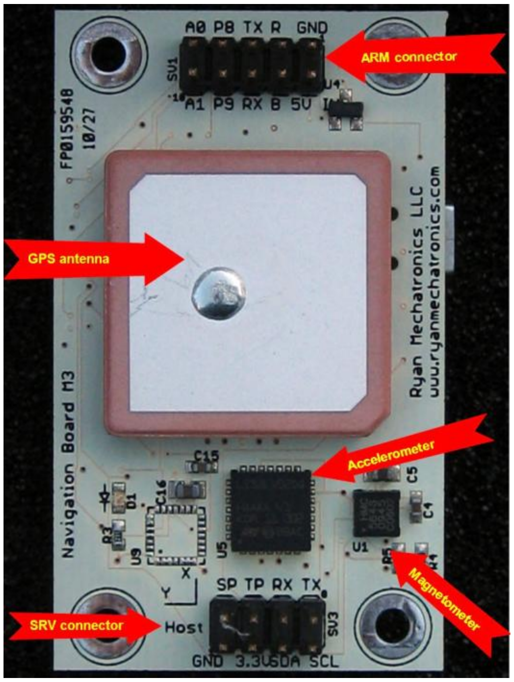
The on board inertial measurement suite includes:
3 axis rate sensors to measure angular rate
3 axis accelerometers to measure linear acceleration
3 axis magnetometer to measure magnetic flux (typically used for compass type heading derivation)

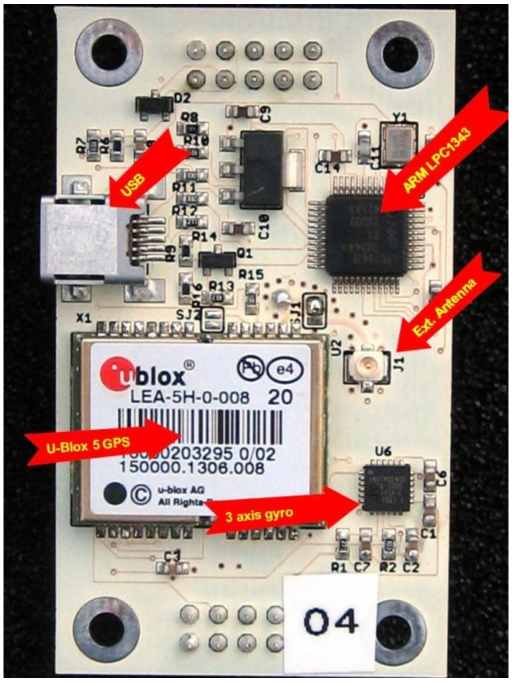
The combination of all these capabilities with the on board ARM processing power allows a full attitude heading reference system (AHRS) with GPS position, velocity and time updates all in one tiny package.

The original NavBoard was designed to be complimentary to the SRV robot built by Surveyor Corporation. The NavBoard M3 augments this design to include the rate sensing capability and on board processing power.

Application areas include, but are not limited to:

- UAVs (AUVs, UAS, etc)
- Robotics
- Education
- Rocket science





1.1 Limitations

The unit, like any IMU / AHRS, can be pushed beyond the limits of its ability to sense any of the measurements it needs to operate correctly. The following list includes results that are known to occur if operation exceeds the limits listed later in this document.

1.1.1 Rate limits

Saturation of maximum rate in any axis for any amount of time will result in an incorrect attitude estimate if an attitude estimator has been hosted on the ARM processor. The longer the saturation duration, the more error will be present in the attitude determination. A good attitude estimator shall recover once saturation has stopped and the internal filter has time to reconverge on the correct solution.

Please note: The NavBoard M3 does NOT ship with an attitude estimator set of code, but it has the processing and code memory to host an estimator of the customers design.

1.1.2 Acceleration limits

Excessive acceleration can include acceleration above the rated levels in continuous application (static / low frequency g's), more elusive vibration (sinusoidal / random) or shock (impulse / random) events that may not show full saturation of the accelerometers in data output, but have affected the sensors internally and corrupted the values. Continued acceleration above the limits or excessive vibration / shock events can corrupt the output acceleration.

1.1.3 Magnetic field limits

Magnetometers are sensitive to hard and soft iron effects, as well as induced magnetic fields from high current. Saturation of the local magnetic field is easily identified, but lower level influence on the sensor can result in pervasive errors as well. Calibration of the unit in the final configuration will help prevent errors introduced by hard iron in the local area. However, induced magnetic fields from high current devices or high power RF circuitry can result in operational errors. After a proper calibration, no axis should exceed a +/- 1 gauss value.

1.1.4 GPS

GPS is a phenomenal technology allowing location of your position on the planet Earth within about a 15 foot (5 meter) accuracy using a module the size of your thumb!

GPS is subject to many possible interference sources, including anything in the GPS frequency band (including harmonics of lower frequencies from digital systems) and other jamming sources, like foliage or direct blockage of the antenna.

This manual cannot begin to educate the user on limits of GPS technology, but we recommend both Wikipedia and the support area on the U-blox (www.ublox.com) website for more information.

1.1.5 Precautions and User Responsibility

The NavBoard is an open electrical device with no case. It has no on board protection from short circuits or accidental electrical damage. No system is fool proof, and all correct use and planning for events in case of failure are the responsibility of the user.

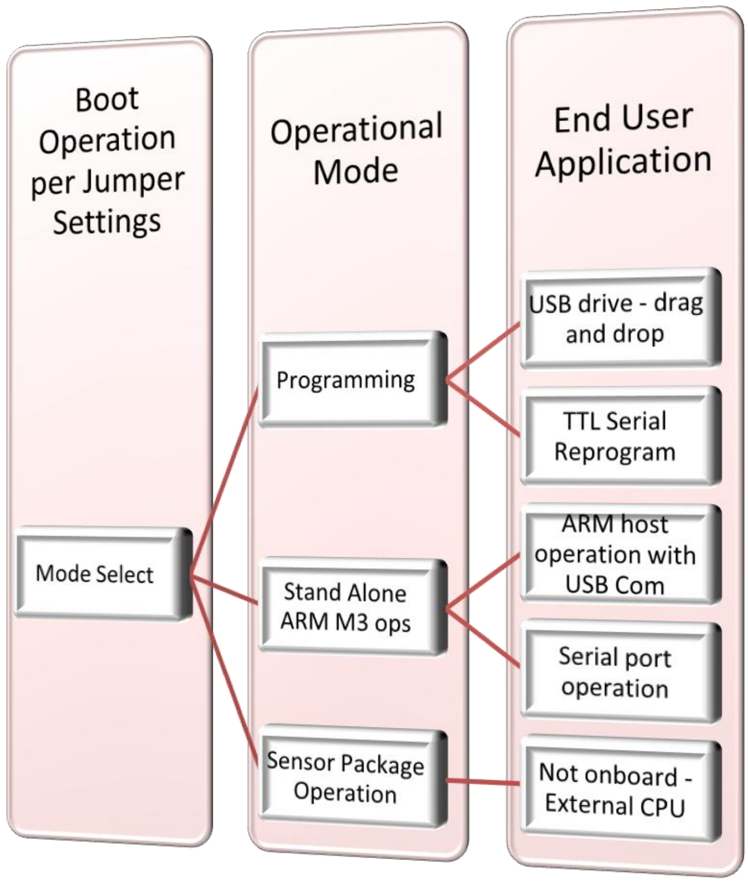
Ryan Mechatronics cannot be held responsible for accidental or intentional damage caused by this unit either directly or indirectly.

1.2 Theory of Operation

The NavBoard is an integrated set of MEMS sensors and GPS that can be managed via an onboard CPU to provide position, velocity, attitude and heading information, along with raw sensor data and other useful information.

The on-board ARM processor can be reprogrammed easily by dragging valid object / bin files into a Windows recognized USB flash drive.

However, the system is designed also to act as a standalone sensor package for use with any host processor.   A top level view of the usage modes is shown in the following figure.



1.2.1 Startup Conditions

The startup conditions of the pins on the NavBoard dictate what mode the system enters.

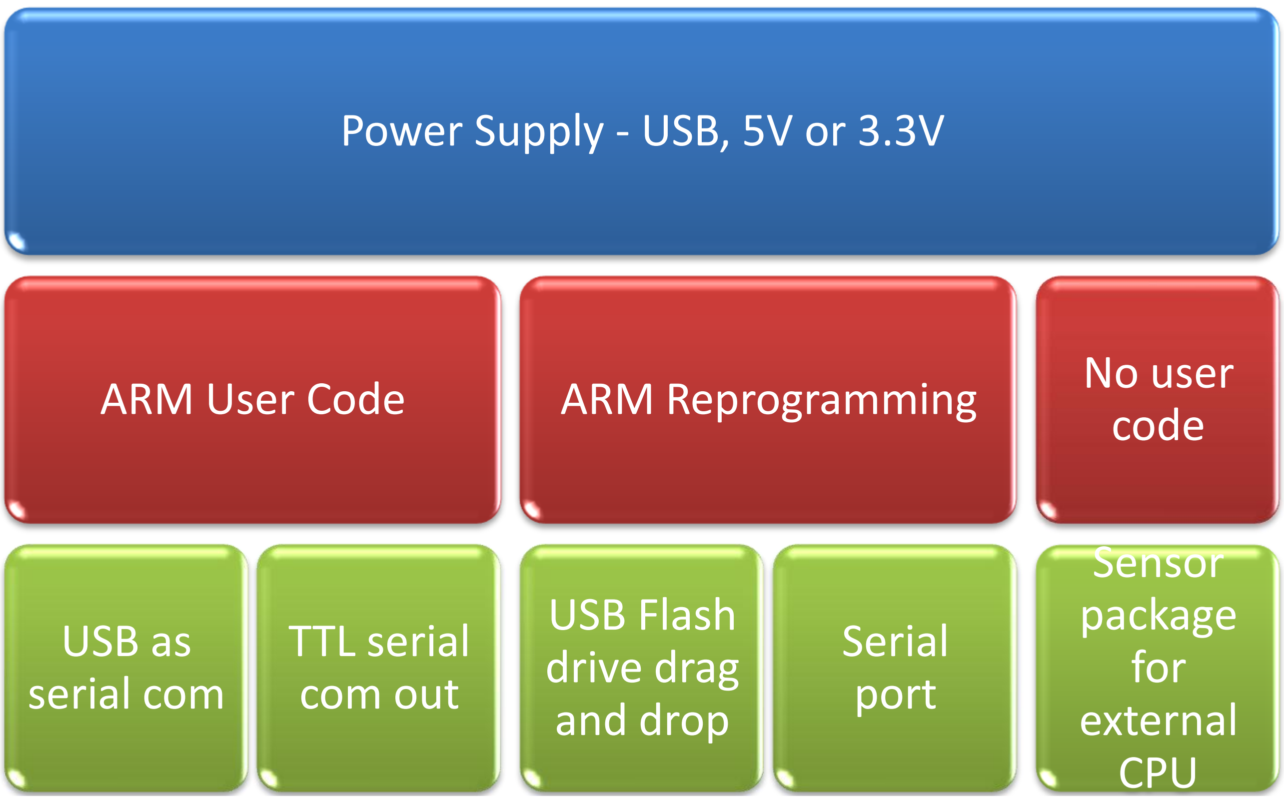
On Board ARM CPU running user code: For operation in standalone mode, user must have code loaded and running on the processor. One code example would use the SP pin on the Host connector (SV2). If that pin is jumped to ground upon boot, then the user code on the ARM processor could look for this condition and decide to run user code or revert to sensor package only operation.

<u>Reprogramming:</u> For operation as a USB drive (allowing easy reprogramming via a drag and drop of a .bin file to the drive), the system should be powered via USB first. If not recognized as a USB drive, then the B pin on the SV1 connector can be momentarily grounded and then released. A Windows system should recognize it as a USB flash drive. Note that this can take 45 to 60 seconds for flash drive initialization.

<u>Sensor Package Only:</u> For operation as a sensor package only (i.e. for use with the SRV robot from Surveyor), the only connections to the unit should be 3.3V, GND, SDA, and SCL. In this condition, no on board ARM processing should occur (provided the user has not overridden this with other software).

1.3 Modes of Operation

The NavBoard has been designed to be simple and effective at providing software flexibility and standalone sensor capability. Specific pins and mode operations are shown below.



2. Specifications and Characteristics

Presented in this section are the sensor and system specifications for the NavBoard. All parameters specified are @ VDD = 3.3 V and Ta = 25°C.

2.1 Performance Specifications – Inertial Sensors

Characteristics	Conditions	Min	Typical	Max	Units
Angular Rate					
Range	All axes		±2000		° / sec
Rate noise density	All axes		0.03		° /sec /
Bandwidth	Maximum, all axes		256		Hz
Sensitivity	All axes		14.375		LSB per ° / sec
Acceleration					
Range	All axes	±2	±2	±6	*g*
Sensitivity	All axes		1024		LSB /g @ 2g
Sensitivity	All axes		340		LSB /g @ 6g
Bandwidth	All axes		Output data rate / 4		Hz
Resolution	All axes		1		m*g*
Magnetic Flux					
Range	All axes		±1		Gauss
Bandwidth	All		10,000		
Resolution	All		7		milligauss

- Specifications are subject to change at any time without notice

2.2 Performance Specifications – Global Positioning Receiver

Characteristics	Conditions	Min	Typical	Max	Units
Position, Velocity and Time					
Time to First Fix	Cold Start Warm Start Hot Start		29 29 <1		s
Horizontal position accuracy	Without SBAS SBAS		<2.5 <2.0		m
Max Navigation Update Rate	Message dependent	2	2	4	Hz
Velocity accuracy			0.1		m/s
External antenna power supply	Center feed on external antenna connection		3.3		*V*

- Specifications are subject to change at any time without notice

2.3 Electrical Characteristics

Characteristics	Conditions	Min	Typical	Max	Units
Power					
3.3V Input Supply Voltage Range	V_{dd} Referenced to GND NOTE: ONLY 3.3V or 5V supply should be applied. Damage can result if both supplies are active	3.1	3.3	3.3	V
5V Input Supply Voltage Range	Note 5V external supply and USB 5V input supply are common	4.65	5.0	5.1	
Current	Average, measured at 3.3V GPS and sensors require minimum 100 mA. Remaining power draw dependent on user code (if any)	100	125	170	mA

- Specifications are subject to change at any time without notice

2.4 Absolute Maximum Ratings

Parameter	Rating
Acceleration (any axis, 0.5 ms) Unpowered	2000g
V_{dd}	-0.3V to +7V
Output Short-Circuit Duration (Any Pin to Common)	TBD
Operating Temperature Range	-30°C to +85°C
Storage Temperature Range	-40°C to +125°C

- Specifications are subject to change at any time without notice

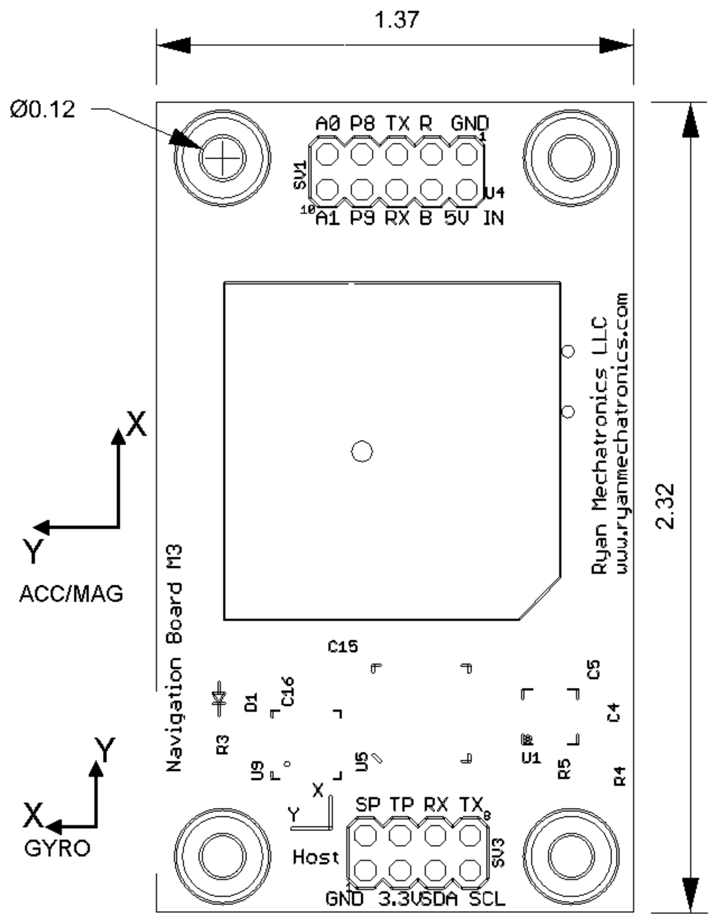
Stresses above those listed under the Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only; functional operation of the device at or near these or any other conditions above those indicated in the operational section of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods of time may affect device reliability.

Drops onto hard surfaces can cause shocks of greater than 2000 *g* and can exceed the absolute maximum rating of the device. Exercise care during handling to avoid damage.

2.5 Mechanical and Pin Assignments

2.5.1 Dimensions

Dimensions for the unit are shown below. All units are in inches.



2.5.2 Coordinate System and Orientation

The NavBoard recently upgraded with a 3 axis MEMS rate sensor. Unfortunately, due to space constraints, it needed to be placed on the bottom of the board. This makes its coordinate system inconsistent with the other sensors and users should be aware of this when using it.

For the accelerometers and magnetometers: The orientation shown (X/Y/Z) frame is the local body frame, with +Z following the right hand rule and coming up out the top of the board. Each of these sensor packages is oriented to this frame.

For the rate sensors: The noted gyro orientation shown in the previous picture gyro has +Z following the right hand rule and oriented down thru the board.

2.5.3 Pin Assignments

Shown below is a graphic of the two connectors and pin names / labels.

The SV1 connector is for use with the on board ARM processor.

If you are using the device in sensor package mode (only I2C with a separate processor), the SV3 connector has all the connections you need (typically GND, 3.3V, SDA and SCL).

Not shown is a pin out for the USB connector, which is described later and can be used for reprogramming and as a serial port.

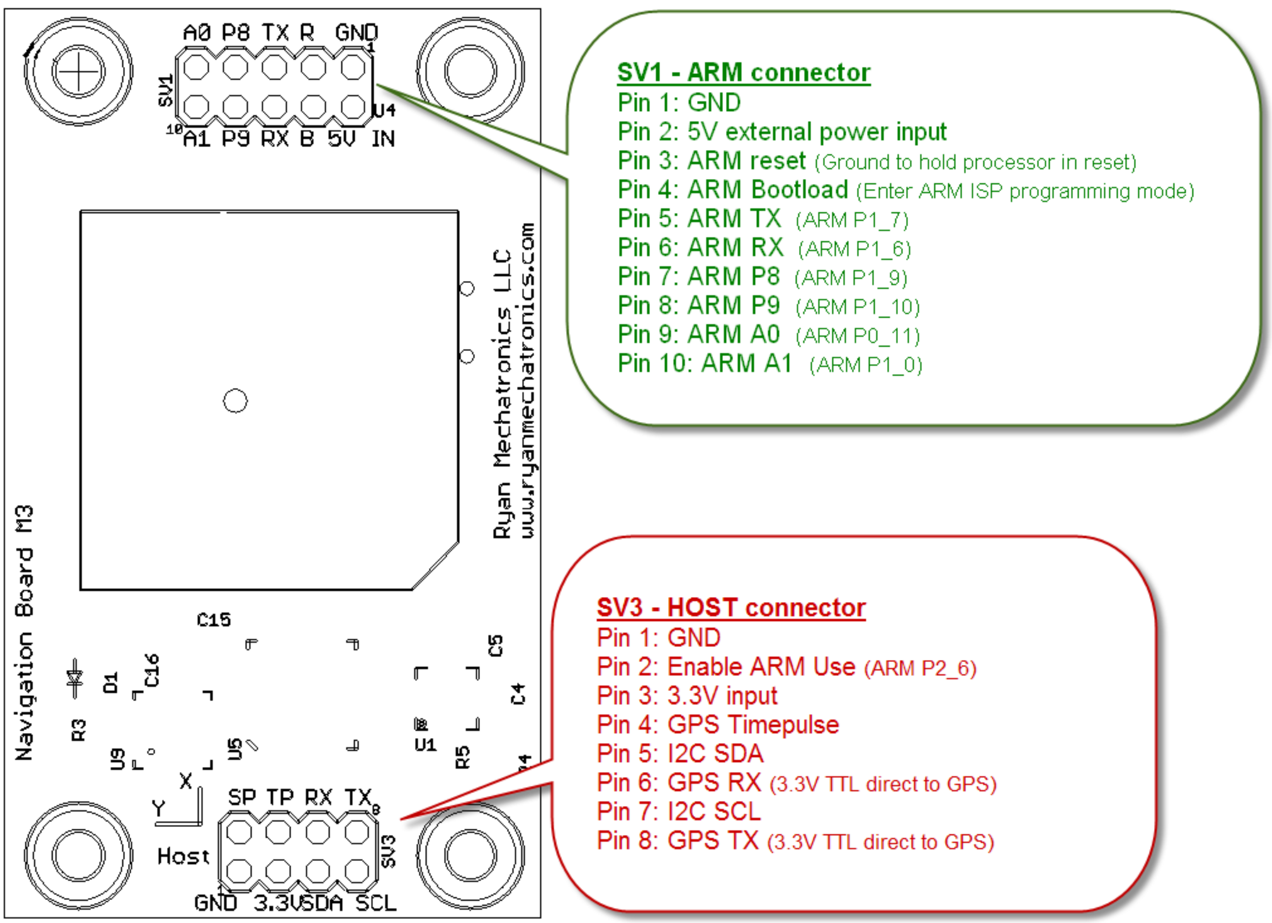


Table 1 - Pin Assignments SV1

Pin #	Pin Label	Pin Name	I/O	Description
1	GND	Ground	N/A	System ground
2	5V	5V	N/A	5V external power. **WARNING**: This power pin is common with USB 5V power and there is no protection. Overvoltage or shorting this pin while it is connected to your computer can damage your computer. If using USB power, do not connect this pin to anything. Use either 3.3V power input, 5V power input, or USB power input. Do not have multiple power sources connected.
3	R	ARM reset	I	Resets on board ARM processor when grounded.
4	B	ARM boot load	I	Forces ARM to enter boot load (programming) mode based on the following conditions: 1) USB power plugged in – momentarily shorting this pin to ground will make the ARM processor be discovered by Windows operating systems as a flash drive. New firmware can be loaded by dragging and dropping the firmware into this folder, then resetting the unit 2) No USB power – Holding this pin low during power application will force the ARM processor into ISP programming mode via its serial port. FlashMagic or other tool is needed to upload software in this manner.
5	TX	ARM Serial TX	O	ARM Serial Port TX 3.3V level Pin 1.7 on processor, can be re-dedicated
6	RX	ARM Serial RX	I	ARM Serial Port RX Pin 1.6 on processor, can be re-dedicated
7	P8	ARM P1_9	I/O	ARM pin 1.9 GPIO
8	P9	ARM P1_10	I/O	ARM pin 1.10 GPIO
9	A0	ARM P0_11	I/O	ARM pin 0.11, can be configured as analog to digital converter
10	A1	ARM P1_0	I/O	ARM pin 1.0, can be configured as analog to digital converter

For ARM pins, please see the LPC1343 User Manual from NXP for other pin options.

Table 2 - Pin Assignments SV3

Pin #	Pin Label	Pin Name	I/O	Description
1	GND	Ground	N/A	System ground
2	SP	Enable ARM Use	I/O	ARM pin 2.6. This pin is a GPIO pin to the on board ARM processor. Originally, this pin was intended (via specific user code) to keep the processor in low power mode unless this pin is grounded on boot. This allows use as a sensor package and as a standalone unit with a simple jumper from this pin to ground. It is at its core just a GPIO pin for the ARM however, and is available for use.
3	3.3V	3.3V	N/A	3.3V power input Use either 3.3V power input, 5V power input, or USB power input. Do not have multiple power sources connected.
4	TP	GPS Timepulse	O	1 PPS output pulse from GPS receiver, can be used to sync external time
5	SDA	Serial Data	I/O	I2C SDA line Board has 10k pull-up resistor on board
6	RX	GPS RX	I	U-blox GPS receiver, 3.3V level RX serial port With TX, can be used in parallel with U-center program to monitor GPS operations
7	SCL	Serial Clock	O	I2C SCL line Board has 10k pull-up resistor on board
8	TX	GPS TX	O	U-blox GPS receiver, 3.3V level TX serial port

3. Sensor Details and I2C addresses

Presented in this section are the references for all sensors and the processor on the board. Answers to questions regarding the sensor details can be found in these data sheets and manuals.

Each device connected to an I^2C bus is identified by a unique 7-bit address (whether it's a microcontroller, EEPROM, etc) and can operate as either a transmitter or receiver, depending on the function of the device. The I^2C addresses are provided here as well.

3.1 GPS

The GPS unit is a U-Blox receiver, the type easily seen on the chip itself. Details can be found at www.u-blox.com.

The default I^2C address for u-blox GPS receivers is set to 0x42. The 7-bit address for this device is 0x42. The 8-bit read address is 0x85. The 8-bit write address is 0x84.

Warning: U-Blox receivers act as a master I^2C device 0.1 seconds after boot up. During this time, it will query for external flash memory at address 0xA0. If you have any devices on your bus with this address, you may experience issues with operation of the GPS. We recommend, if this is the case, to disable the device at 0xA0 until 150 msec after boot to prevent any issues. None of the chips on the NavBoard have this address, it would only be important for custom user designs.

3.2 Accelerometers

The 3 axis accelerometer is the LIS3LV02DQ unit from STMicroelectronics. Details can be found at http://www.st.com/stonline/products/literature/ds/11115.htm . The 7-bit address for this device is 0x1D. The 8-bit read address is 0x3B. The 8-bit write address is 0x3A.

See future upgrades for more information regarding coding for this device.

3.3 Rate Sensors

The 3 axis rate sensor is the ITG-3200 from Invensense. Details can be found at http://invensense.com/mems/gyro/itg3200.html. The 7-bit address for this device is 0x68. The 8-bit read address is 0xD1. The 8-bit write address is 0xD0.

3.4 Magnetometer

The 3 axis magnetometer is from Honeywell, model HMC5843. Details can be found at www.magneticsensors.com/datasheets/**HMC5843**.pdf. The 7-bit address for this device is 0x1E. The 8-bit read address is 0x3D. The 8-bit write address is 0x3C.

3.5 ARM processor

The ARM processor is an LPC 1343. Software programming examples can be found at www.nxp.com , http://ics.nxp.com/microcontrollers/to/pip/LPC1311.html, and the datasheet is located here: http://www.nxp.com/documents/data_sheet/LPC1311_13_42_43.pdf.

To enable I^2C communication as a slave requires programming by the user, and the slave address can be defined at that time.

3.6 Planned Future Upgrades

The next version of the NavBoard will likely replace the magnetometers and accelerometers with a combined device, the LSM303DLH from STMicroelectronics (http://www.st.com/stonline/products/literature/ds/16941.pdf).

The magnetometer address and protocol remains the same for this device.

The protocol for the accelerometer will change by a minor amount and its address changes. The 7-bit address for this device is 0x18. The 8-bit read address is 0x31. The 8-bit write address is 0x30.

Please write your code in a modular fashion to take advantage of this future upgrade.

4. Hardware Integration

Presented in this section are selected hardware interface comments to help ease integration of the unit in the end user system.

Please note - the NavBoard is an open electrical device with no case. It has no on board protection from short circuits or accidental electrical damage. No system is fool proof, and all correct use and planning for events in case of failure are the responsibility of the user.

Ryan Mechatronics cannot be held responsible for accidental or intentional damage caused by this unit either directly or indirectly.

4.1 Power

4.1.1 Input Power

The NavBoard core electronics all operate off of 3.3V. There are three methods for powering the board however. 3.3V input, 5V input, or USB (5V) input.

If you have 3.3V available, the most efficient method is to supply the NavBoard via the 3.3V connection on SV3. This is ideal for using the unit as a sensor package where a separate CPU is being used to acquire and use the data via I2C.

The 5V input on SV1 is common to the USB power bus. If you provide 5V power to the board, the onboard regulator will generate 3.3V output for the electronics.

Do NOT supply more than one power supply to the unit (i.e. 3.3V and 5V, or USB power and 5V). This will ultimately lead to damage of the NavBoard or your PC.

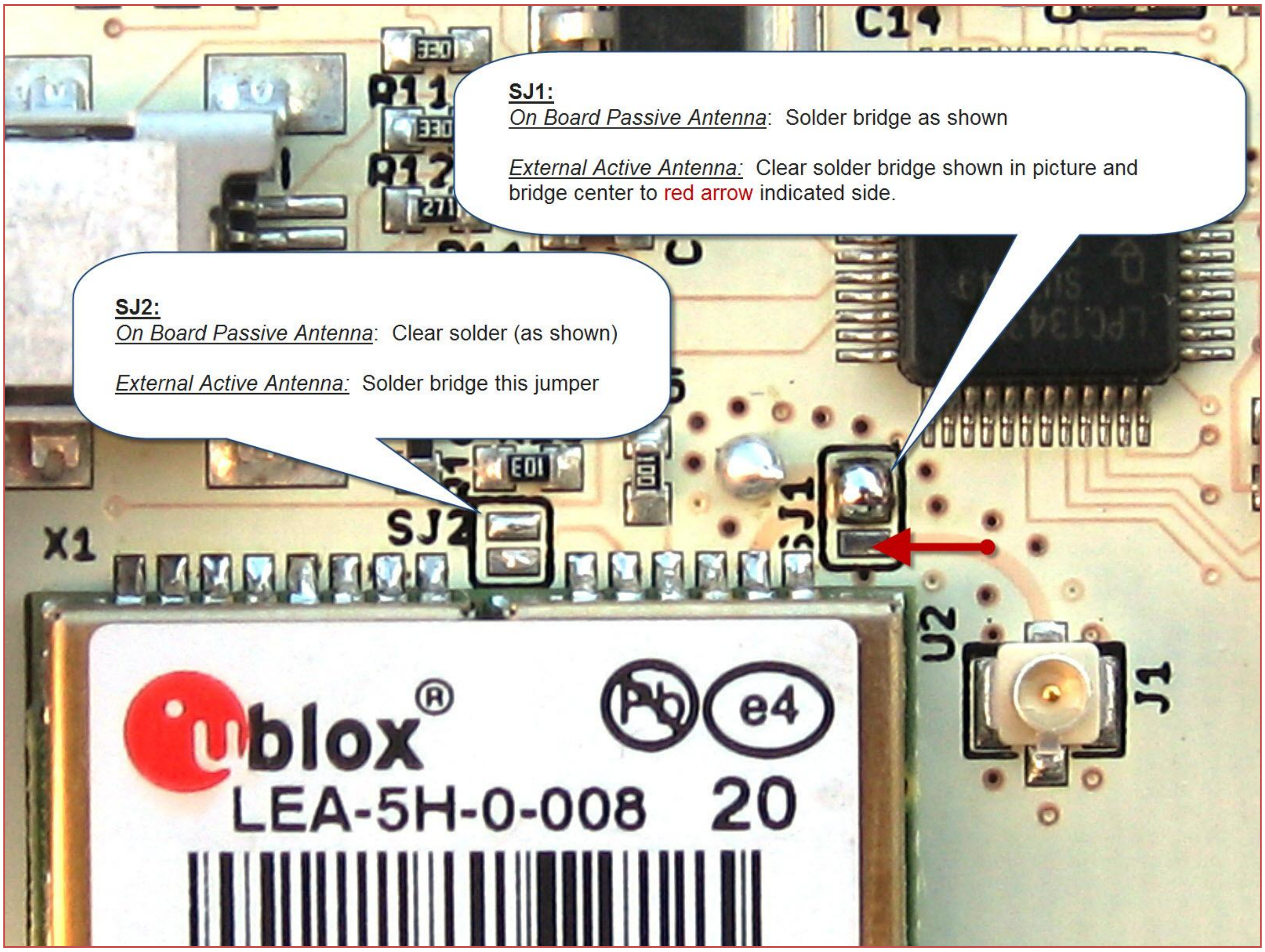
Critical Warning: When using USB power, the bare circuit board is powered by your USB port. Shorting the unit out or overvoltaging it can directly damage your PC. Take extra precaution when using it directly interfaced to your PC.

4.2 GPS Antenna Options

The NavBoard has an on board passive antenna for GPS reception, but with a solder jumper and user supplied antenna, allows an external antenna to be used instead.

There is a u.FL connector (J1) on the back of the unit that can be used to interface to an off board active antenna (3.3V power supplied by the NavBoard). You may need an interface cable (e.g. Digi-Key p/n A36232-ND) to interface to your active antenna. There are many options for antennas, but the board was designed for a 3.3V active L1 GPS antenna.

The graphic below shows how to enable / disable the onboard passive antenna or the external antenna. Only one or the other may be used at one time.



4.3 Configurations

There are two primary configurations for the board. Standalone operation and sensor package operation. These configurations are described here.

4.3.1 Sensor Package Mode

In this mode, the on board ARM processor is not used at all. The I2C bus lines are used by a separate host processor (like the SRV robot from www.surveyor.com) to acquire inertial and GPS data.

In order to keep the ARM processor from interfering with the host processor, there are three things that can be done:

- **HW Option:** Keep ARM in reset by tying the ARM reset pin on SV3 to ground
- **SW Option 1:** Program the ARM processor with specific software preventing use of the I2C bus
- **SW Option 2:** Wipe the ARM processor by programming no firmware at all

Both software option builds are available from www.ryanmechatronics.com.

4.3.2 Stand Alone Operational Mode

In this mode, the on board ARM processor acts as the master on the I2C bus and manages all inertial sensors and GPS acquisition. Output data can be seen on the serial ports.

In this mode, the user is responsible for the software on the unit. Software example code is available at www.ryanmechatronics.com. Pre-built bin files to accomplish simple data acquisition and output are provided there as well.

4.3.2.1 Communication in StandAlone Mode

There are two methods of communication available in StandAlone mode, USB serial port and TTL serial port. User program on the ARM processor determines which communication protocol can be used.

USB communication is accessed via the USB mini-B connector.

TTL serial (3.3V level) is accessed via the TX/RX pins on the SV1 connector only. Note that the SV3 connector, which has pins labeled TX and RX, is not the ARM serial port. Those pins are for accessing the serial port on the GPS receiver.

These methods are enabled and controlled via software, and are not both active at one time (currently).

The UART is a 3.3V level interface. The unit does not support hardware handshaking. Do NOT interface with a standard RS-232 port, as the voltages on that port will damage the unit. An external adapter that uses 3.3V to convert to RS-232 levels can be powered from the onboard 3.3V regulator.

4.4 Special Interface Pins

The NavBoard utilizes external pins to help with user programming of the unit (not necessary if used as a sensor package only). These pins are described here.

4.4.1 ARM Reset – SV1, Pin 3

This pin will hold the on board ARM processor in reset if grounded. This guarantees the ARM will not be operating f using the unit as a sensor package only.

It can also be momentarily grounded to reboot the ARM.

This reset pin is ONLY for the ARM. If any other sensors need to be restarted, you must cycle power to the unit.

4.4.2 ARM Boot load – SV1, Pin 4

The ARM processor was intended to host user code. There are two ways to download new code to the processor. The first is via the USB port. The second is via the serial port. Reprogramming is accomplished via an on board boot loader in the processor.

4.4.2.1 USB reprogramming

If USB power is being used (i.e. the unit is plugged into a PC), then momentarily shorting this pin to ground will make the ARM processor be discovered by Windows operating systems as a flash drive. New firmware can be loaded by dragging and dropping the firmware into this folder, then resetting the unit.

4.4.2.2 Serial port reprogramming

If external power is used and USB is not connected, then the unit can be reprogrammed via the serial port. Holding the ARM Boot load pin low during power application will force the ARM processor into ISP programming mode via its serial port. Flash Magic or a similar tool is needed to upload software in this manner.

5. Software Interface

The NavBoard software and support GUI is open source and can be found at www.ryanmechatronics.com.

5.1 Firmware Upload Procedure

The easiest method to upload new firmware to the ARM processor is via USB. Follow these simple steps:

1) Short the "B" pin to Ground on SV1
2) Plug unit via USB into a PC running Windows (XP, Vista, 7)
3) Remove the shorting wire from step 1
4) Windows will recognize the unit as a flash drive. This may take 30 to 45 seconds the first time.
5) Move the desired firmware to the flash drive from your PC (just drag and drop!).
   a. The filename MUST be "firmware.bin"
6) When complete (a few seconds), close the flash drive folder. Disconnect and reconnect the USB cable (or reset the processor by shorting the "R" pin to ground momentarily on SV1.

5.2 Serial Port via USB

If the firmware loaded supports USB serial com, Windows will identify the unit when plugged in as a serial port, but you may need to point at the correct INF file so it can correctly recognize it. The INF file for the LPC1343 processor to act as a serial port is named lpc134x-vcom.inf and is located here:

www.ryanmechatronics.com/public_files/software/NavBoardM3/lpc134x-vcom.inf

5.3 Recommended tools

We highly recommend using Rowley Crossworks (http://www.rowley.co.uk) Crossworks for ARM as the tool for reprogramming the NavBoard. Rowley tools are very simple to use and based on the GCC compiler chain.

We also recommend the tools and evaluation boards from microbuilder.eu (http://www.microbuilder.eu/home.aspx). They have an excellent set of prototyping boards, tools and advice. Much of the software package that has been used as one core for programming the NavBoard can be found in their LPC 1343 reference design via open source license.

5.4 Native Software Description

The Nav Board can ship with or without native software. The native software code and a GUI (including source) is located here:

http://code.google.com/p/navboard-m3/source/browse/#svn%2Ftrunk%2FGoogleHosted

The nav board operates at 115k baud (serial version) or any baud rate (USB version), 8 bits, 1 stop bit, no polarity and no handshaking. The native software has three modes: BIT, ASCII output and BINARY output.

5.5 Native Software Input

The Nav Board accepts ASCII characters to change mode:

Table 3 – Mode Change Commands for Nav Board

ASCII command	ASCII value	Resultant Mode	Mode Description
0	0x30	ASCII	Outputs ASCII (human text readable) GPS and sensor data.
1	0x31	BINARY	Outputs binary GPS and sensor data
2	0x32	BIT	Outputs summary text message showing status of GPS and sensors

5.6 Native Software Output

The Nav Board outputs the following message content per mode.

Table 4 – Output Data for Nav Board

Mode	Output Description
ASCII	String output has the following fields: G, GPS fix, Number of GPS sats in track, UTC, Latitude, Longitude, altitude A, 99, AccX raw counts, AccY raw counts, AccZ raw counts R, temperature, RateX raw counts, Rate Y raw counts, Rate Z raw counts M, 99, MagX raw counts, MagY raw counts, MagZ raw counts I,GPIO0,GPIO1,GPIO2,GPIO3,GPIO4,GPIO5,GPIO6 V,ADC 0 counts, ADC 1 counts Scaling of raw counts to useful numbers is left to the user, but the following applies: Accelerometer: Accel (m/s^2) = raw counts / 1024.0 * 9.8 Rate sensor temperature: data->temp = 35.0 + ((raw_temp + 13200)/280.0); //Gyro scaling: 14.375 LSB/degrees/sec Rate sensor scaling: rate (deg/s) = raw counts / 14.375

BINARY	Outputs binary GPS and sensor data, scaled in a binary format with the following format:
	
	mBinOut[0]=0xAE; //Header
	mBinOut[1]=0xAE; //Repeated header
	mBinOut[2] = (size of this array, typically 88)
	mBinOut[3-> 37] = GPS_Data //
	mBinOut[38->50] = accelerometer data (m/s^2 units)
	mBinOut[51->67] = temperature and gyro data (rad/s units)
	mBinOut[68->80] = magnetometer data (gauss)
	mBinOut[81->85] = ADC raw data
	mBinOut[86->87] = GPIO

BIT	Outputs summary text message showing status of GPS and sensors Ryan Mechatronics ----------------- Nav Board M3 Built In Test Acc: LSM303 Gyro: ITG-3200 Mag: HMC 5843 GPS: U-Blox